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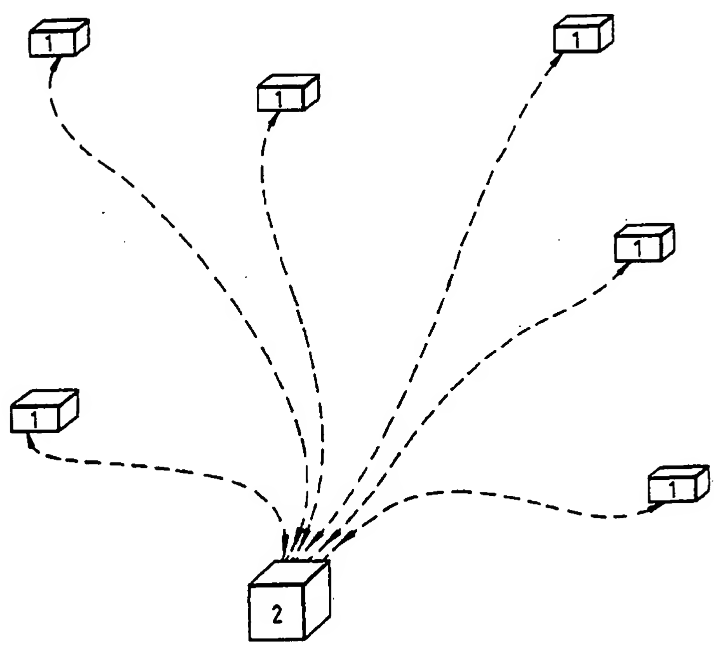

(57) Abstract

A particle monitoring system to monitor certain properties of individual particles particularly as a function of time. Separate particle monitors (1) record and store data, each having their own key-pad and visual display unit. The data is read and processed by the central master computer (2), which represents the data graphically as a function of time and/or location.

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PARTICLE MONITORING SYSTEM

This invention relates to a particle monitoring system, in particular a system for monitoring temporal changes in the size and population spectra of particles in a given fluidic environment.

In the context of the present invention, the term 'particles' is intended to apply to both solid bodies and drops of liquid.

Particle analysers are known for example, as described in UK Patent Application No 2022816A in which the size and, to a certain extent, shape of the ambient particles can be determined.

Many such analysers make use of the scattering of light by a particle passing through a beam of radiation. These provide useful data on the properties of particles at a given location.

In the case of airborne particles it is useful to have information on the particles at various locations through which the fluid concerned is spread, and particularly to have information as to the change in various properties of the particles, for example size and population, as a function of time.

A present monitoring system is described in UK Application No GB 2132767A which employs a number of monitoring devices set at separate locations and a receiving means to respond to signals from the monitoring devices. The system is more specific to the measuring of water content and has the disadvantage of not giving any information as to temporal changes in the moisture content of the medium in which the monitoring devices are placed, but merely gives readings taken by the separate monitors over very short periods of time. A further disadvantage of this system is that the monitors themselves cannot store information and so have to be connected up separately to the central receiving unit where the information is stored.

There is therefore a need for a monitoring system for monitoring the properties of individual particles in a fluidic environment and which gives information on the temporal changes of such properties as well as a function of location and which has the added advantage of including remote intelligent monitors.

According to the present invention a particle monitoring system includes a plurality of independent particle monitors spatially separated and under the control of a master computer, wherein each particle monitor employs laser light scattering techniques for

detecting and analysing individual particles in its vicinity, and stores the results over a given time period, the stores results being readable by the master computer for processing functions.

The processing functions may include the representation of the stored results as a function of time and/or location in graphical form.

Thus temporal and spatial changes in various parameters, such as size and population of the particles in an environment can be recorded and analysed by the system.

With regard to the individual monitors they may take any suitable form but preferably each comprises a first scatter chamber including a first concave reflector, a sample of fluid in the form of a laminar flow intercepting at right angles a beam of radiation at the focal point of the first concave reflector, and a second chamber leading from an aperture in the first chamber. Light scattered by the individual particles in the sample is directed towards radiation collectors, converted into electrical signals, and analysed. Such monitors are further disclosed in co-pending Applications (applicants references P0543WOD claiming priority from UK patent application No. 8726304 and P0544WOD claiming priority from UK patent application No. 8726305) by the same inventors.

With a number of such monitors spatially separated but operating in synchrony, the behaviour of aerosols in terms of changes in population density, size distribution, and dispersion rates can be analysed as a function of time.

The system may have a present alarm capability, so that when the system detects given conditions, an audible or visual alarm is triggered.

An embodiment of the invention will now be described by way of example only with reference to the accompanying drawings of which:-

Fig 1 is a schematic diagram of the deployment of several Particle Monitors in communication with a Central Master Computer.

Fig 2 is a schematic diagram of a single Monitor.

Fig 3 is a schematic diagram of the electronic processing system.

Referring to Figure 1, a number of independent monitors 1 are operated under the control of a central master microcomputer 2. If only two monitors are deployed the master microcomputer is not absolutely necessary for possible processing of recorded data to reveal behavioural trends. The master microcomputer is typically a

commercial microcomputer, such as IBM-PC or an Olivetti M24, with custom interface electronics. Unlike the monitors (which would be battery powered), the master microcomputer 2 requires mains power. In operation, each monitor functions under its own real-time calendar clock. The clocks are used to control the acquisition of data and can be used to initiate a synchronised start between several remote monitors, the start-time having been programmed into the monitor some time earlier. Alternatively a synchronised start can be generated by radio-control or by fibre-optic link 3 from the master computer.

When in operation, each monitor 1 draws in ambient air by means of an electric pump, detects and measures each individual particle in the air at high throughput rates by means of laser light scattering, and records the results of each measurement in non-volatile memory.

Each monitor 1 communicates with the central computer 2 via radio or optical fibre links 3 or by means of a removeable memory module.

As can be seen from the schematic diagram of a single monitor 1 in Figure 2, an electrically driven pump 4 draws in sample air 5 from the environment together with sheath air 6 through the filter unit 7. The sheath air 6 confines the sample air-stream 5 by means of lamina focussing so that it passes accurately through the scattering volume at the focus of the reflector 8. A laser diode 9 (typically a Philips type 513 CQL) operating at a wavelength of 850nm and a continuous wave power of 20mW produces an output beam 10 which is focussed so as to intercept orthogonally the same air-stream 5 at the scattering volume. The cross-section of the beam 10 at the intersection point is approximately 30μm deep by 4mm across. Particles carried in the sample air-stream 5 generate scattered light pulses as they pass through the laser beam 10 and the reflectors 8 converge this scattered light to light detector points. At these points are placed miniature photomultiplier tube detectors 11 (typically Hammamatsu type R632) which convert the optical pulses to electrical pulses which are then directed to the processing electronic circuitry.

The functional elements of the electronic and computational hardware are depicted in Figure 3. A dual microprocessor system is employed - one committed to data acquisition and recording 12 and the other to system control 13. In operation, current pulses from the photomultiplier detector 11 pass into high-speed digital peak-detect

circuits 14 which output binary values corresponding to the maximum value of the pulses. These binary values are then used as addresses to a look-up table which translates the pulse magnitudes to equivalent particle sizes. Each of the (probably 20) size intervals is represented by a 24-bit counter (ie, 0 to 16 million) and the final output histograms, stored in the memory module, show the values of all counters at the end of each integration period.

The memory module 15 comprises pages of random-access-memory (RAM), each of 32K bytes, and numbering up to a possible 256 pages. It is anticipated that no more than 16 pages (or 0.5 MBYTES) of RAM will be necessary.

Each monitor is equipped with a simple key-pad and display, so that operational parameters can be entered and results can be observed in the field. The memory module 15 of each monitor 1 is preferably removable so that the data can be returned to the master microcomputer 2 (if used) for more detailed processing without disturbing the location of the monitors. Spare memory modules can be plugged into the monitor to continue data collection if required.

The results of the particle detection on each monitor is stored in the form of histograms, each histogram representing the particle size spectrum (ie, number of particles versus size) recorded over a precise time interval or integration period. Associated with each histogram is a time-code and an identity-code for later post-processing use. This integration period is user-definable, and can vary from, say, 100ms (allowing 10 histograms to be recorded per second), to several minutes. The data storage capacity of the monitor would normally be sufficiently large for data to be continuously recorded for a period from minutes up to several hours, the only limit being that of the built-in memory capacity, and the battery capacity.

The monitors are designed to detect individual particles in the range of 1 to 15μm equivalent diameter at maximum rates in excess of 30,000 per second, and to size the particles into a number of size windows, typically of 1μm intervals. Additionally there may be over-range and under-range windows. They collect data over user definable integration period which may be varied from 100ms to 5 minutes, and store the results in non-volatile memory together with elapsed time and identity codes. They can repeat the previous step continuously

over a defined run-time which may be varied from 1-10,000 integration periods. The detection run-time of the monitors may be initiated by means of a front-panel switch, a real-time operated delay switch, or, as an optional extra, by remote control using radio or fibre-optic link. The monitors may display on request, using a built-in LCD display, numerical graphical representations of the temporal changes in size spectra recorded over the run-time or any part of the run-time. The monitors are designed to accept user definable alarm conditions and generate an audible (or visual) alarm when these conditions are met. Such conditions may be, for example, a rapid increase in particle count in one or more specified size windows, a particle count which exceeds a pre-specified value, etc. More complex alarm conditions may also be incorporated. For example, the monitor memory could store the size spectrum of a specific aerosol and generate an alarm when the incoming ambient air produces a similar spectrum to within predetermined thresholds. Such conditions would be implemented in software and thus may be modified to suit experimental requirements.

The monitors are also designed to display their current operational status, including overall count rates, battery status, elapsed run-time, specified integration period, alarm conditions in operation etc (to users requirements). The system allows the transfer of recorded numerical data in the memory module 15 to an external printer and also allows it to be removed and interrogated using the remote master microcomputer system.

The nature of the microcomputer system and the post-processing functions it performs could vary for specific experimental conditions, but the functions performed would generally include the following:- The plotting of graphical data representing the change in recorded size spectra from a single monitor as a function of elapsed run-time; the plotting of graphical data representing the change in particle population density in one specific size interval as a function of elapsed run-time; and if data was recorded simultaneously from several monitors placed at specific locations, then graphical data could be plotted representing the change in particle spectra not only as a function of elapsed run-time but also as a function of geographical location.

The embodiment of the invention disclosed above relates to the detection and analysis of Airborne particles, but the Particle Monitoring System could work equally well to detect any Fluid-borne particles with some alterations to the optical scattering chamber.

Although this invention has been described by way of example and with reference to possible embodiments thereof, it is to be understood that modifications or improvements may be made without department from the scope of the invention as defined in the appended claims.

CLAIMS

What is claimed is:-

1. A particle monitoring system including a plurality of independent particle monitors spatially separated and under the control of a master computer, wherein each particle monitor employs laser light scattering techniques for detecting and analysing individual particles in its vicinity, and stores the results over a given time period, the stored results being readable by the master computer for processing functions.

2. A particle monitoring system as claimed in Claim 1 wherein one of the particle monitors is the control computer.

3. A particle monitoring system as claimed in Claim 1 or Claim 2 wherein the processing functions include the representation of the stored results as a function of time.

4. A particle monitoring system as claimed in Claim 1 or Claim 2 wherein the processing functions include the representation of the stored results as a function of location.

5. A particle monitoring system as claimed in Claim 3 or Claim 4 wherein the representation of the stored results is a graphical representation.

6. A particle monitoring system as claimed in Claim 3 or Claim 4 wherein the representation of the stored results is by a histogram.

7. A particle monitoring system as claimed in any one of Claims 3 to 6 wherein the representation is of population density of the individual particles detected.

8. A particle monitoring system as claimed in any one of Claims 3 to 6 wherein the representation is of size distribution of the individual particles detected.

9. A particle monitoring system as claimed in any one of Claims 3 to 6 wherein the representation is of dispersion rates.

10. A particle monitoring system as claimed in any previous Claim wherein each particle monitor includes a removeable memory module.

11. A particle monitoring system as claimed in any previous Claim wherein each particle monitor is equipped with a key pad and visual display unit.

12. A particle monitoring system as claimed in any previous Claim wherein the independent particle monitors are connected to the master computer by radio-control or fibre-optic links.

13. A particle monitoring system as claimed in any previous Claim wherein the independent particle monitors act synchronously.

14. A particle monitoring system as claimed in any previous Claim wherein the monitors are capable of responding to a predetermined alarm condition.

15. A particle monitoring system as claimed in any previous Claim wherein the alarm condition is triggered by the increase in particle count above a predetermined level.

16. A particle monitoring system as claimed in Claim 14 wherein the alarm condition is triggered when a predetermined spectrum is identified.

17. A particle monitoring system as claimed in Claim 16 wherein the alarm condition activates an audible or visual alarm or both.

18. A particle monitoring system as herein described with reference to the accompanying drawings.

Fig.1

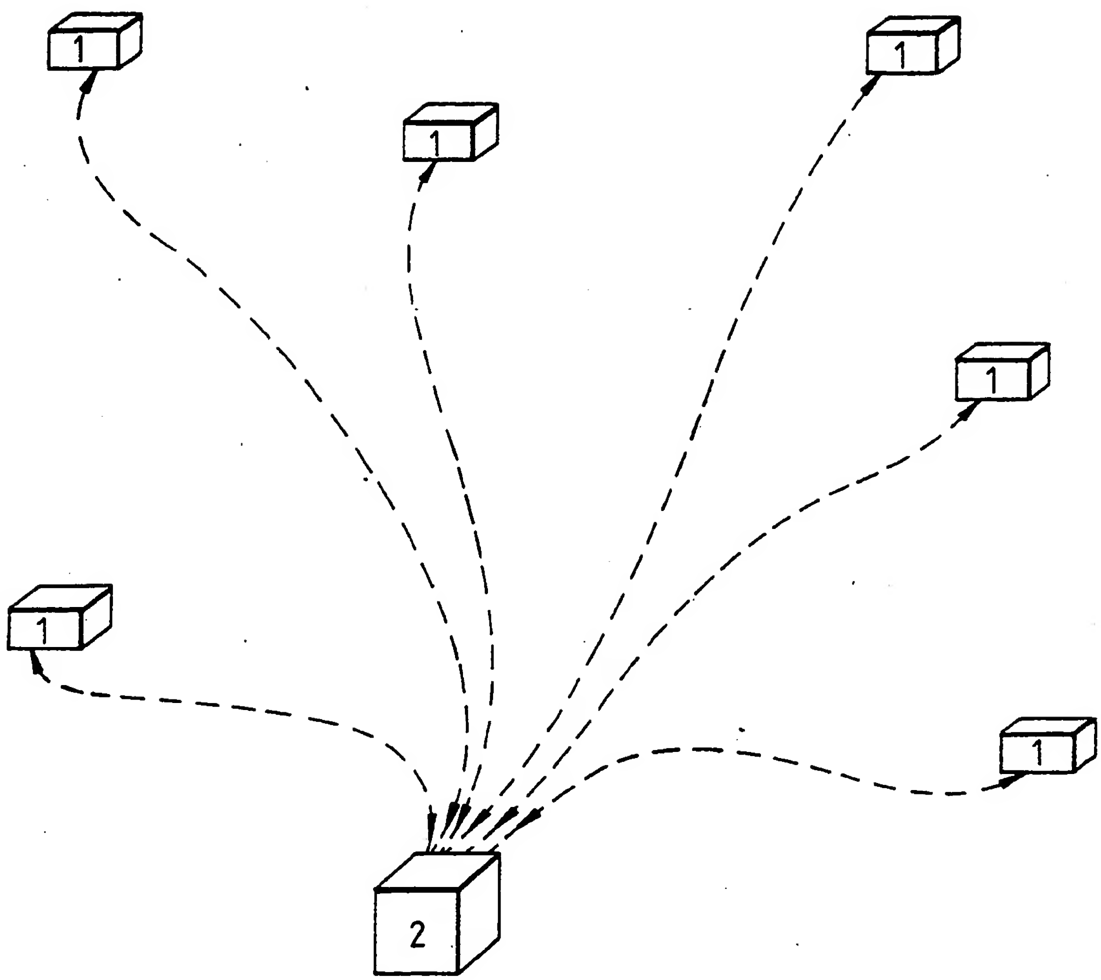


Fig.2

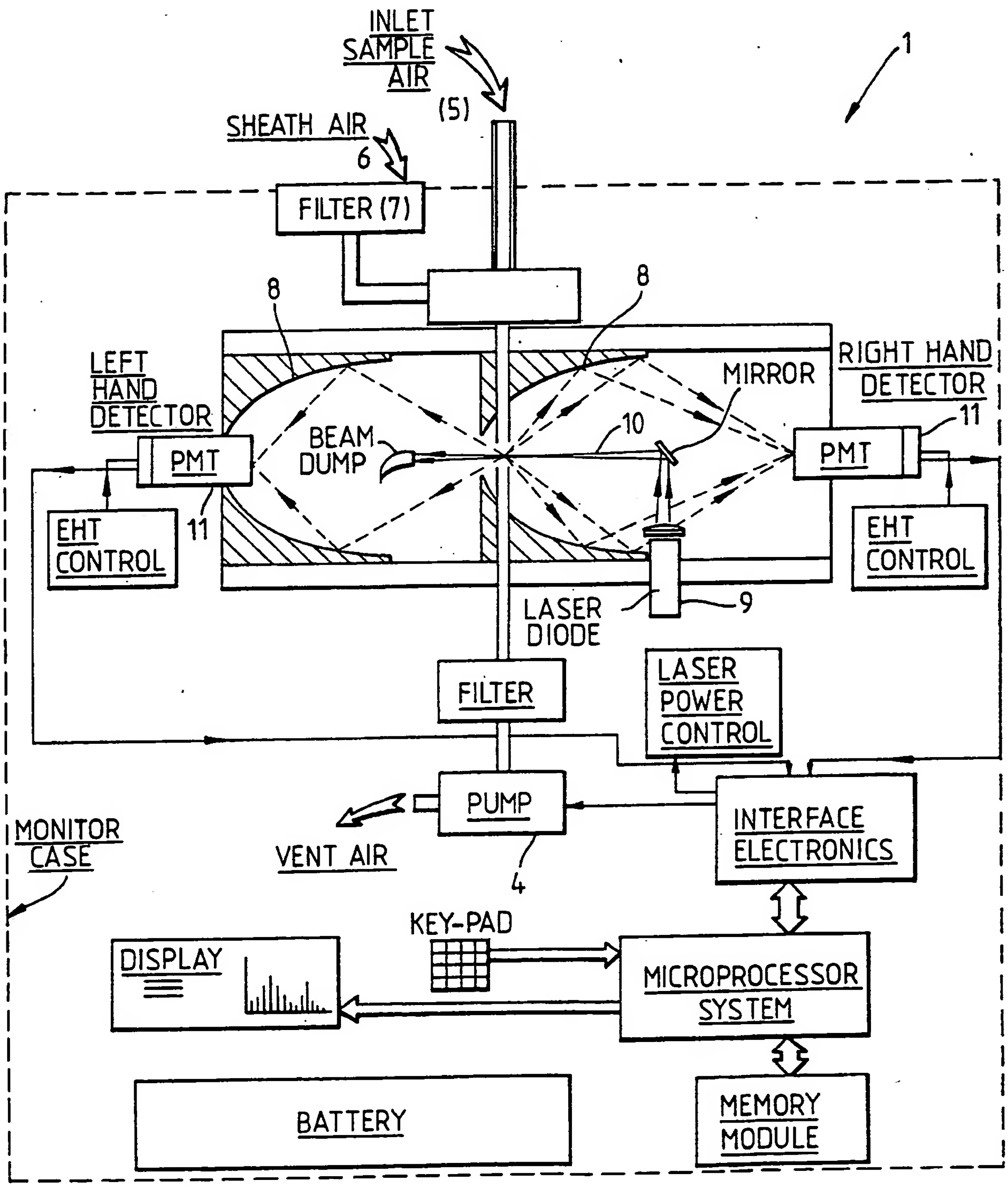

INLET
SAMPLE
AIR
(5)
1
SHEATH AIR
6
FILTER (7)
8
8
LEFT
HAND
DETECTOR
RIGHT HAND
DETECTOR
MIRROR
BEAM
DUMP
10
11
PMT
PMT
11
EHT
CONTROL
EHT
CONTROL
LASER
DIODE
9
FILTER
LASER
POWER
CONTROL
PUMP
INTERFACE
ELECTRONICS
MONITOR
CASE
VENT AIR
4
KEY-PAD
DISPLAY
MICROPROCESSOR
SYSTEM
BATTERY
MEMORY
MODULE

Fig.3

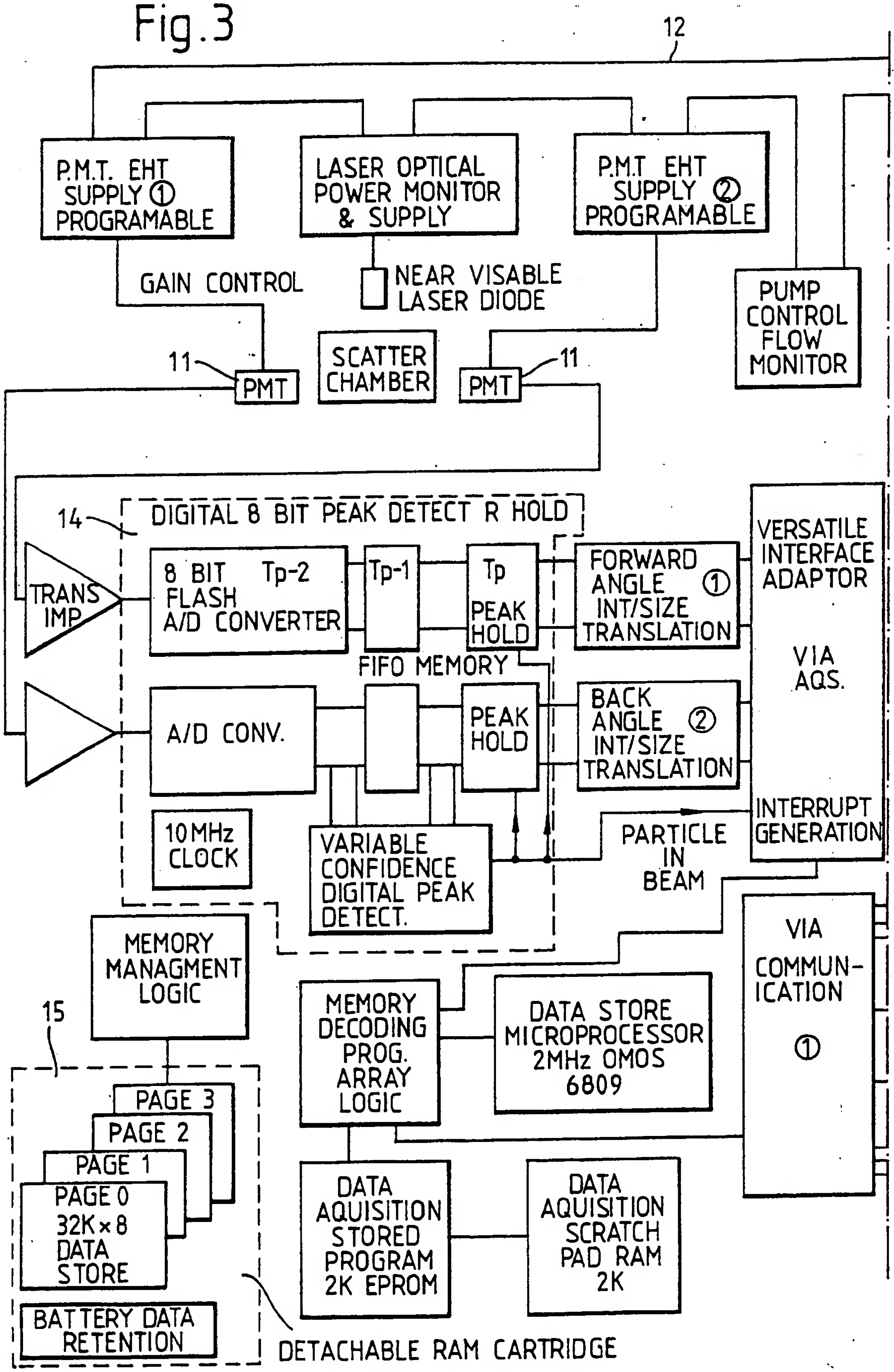
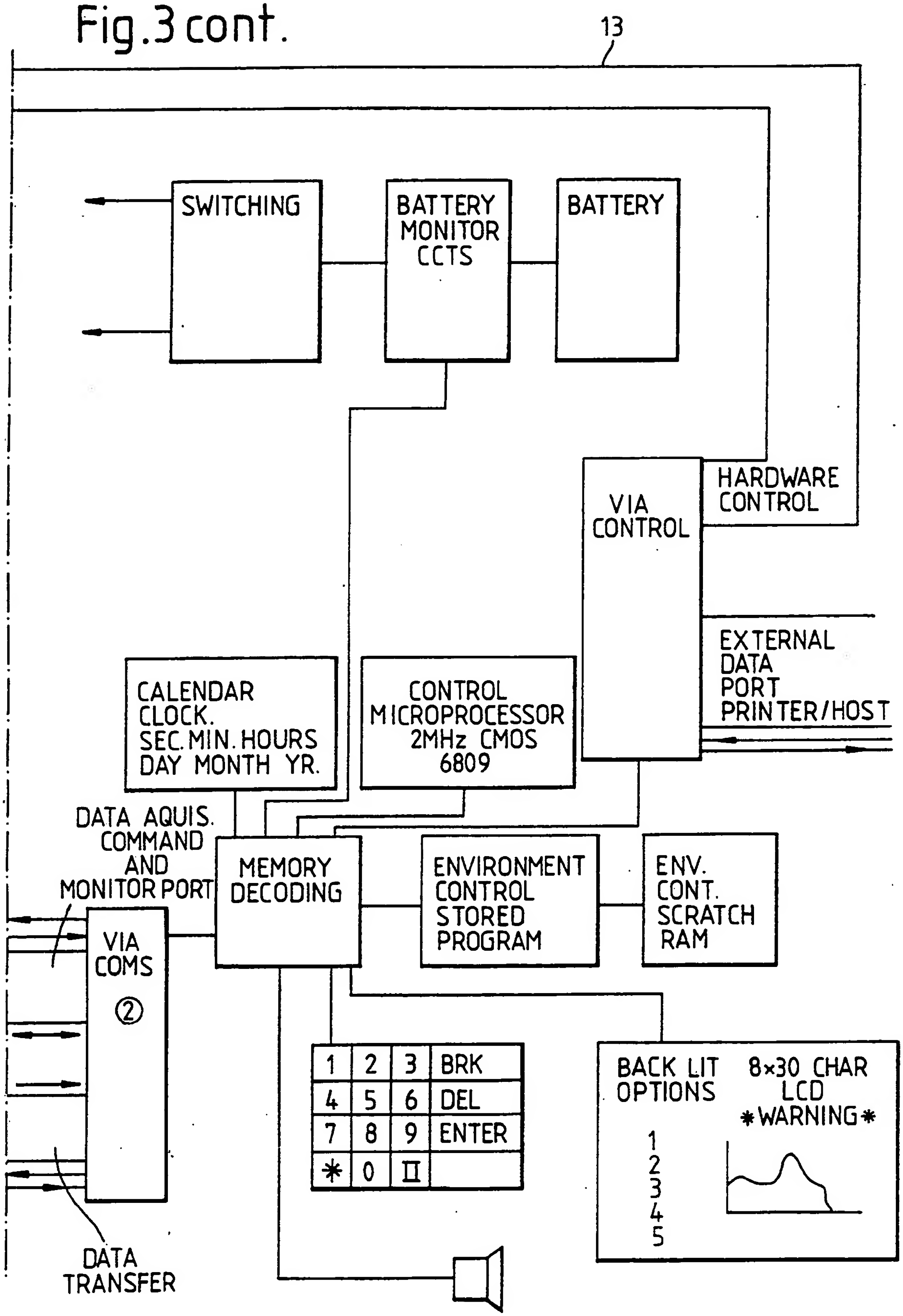

12
P.M.T. EHT SUPPLY ① PROGRAMABLE
LASER OPTICAL POWER MONITOR & SUPPLY
P.M.T. EHT SUPPLY ② PROGRAMABLE
GAIN CONTROL
NEAR VISABLE LASER DIODE
PUMP CONTROL FLOW MONITOR
11
PMT
SCATTER CHAMBER
PMT
11
14
DIGITAL 8 BIT PEAK DETECT R HOLD
TRANS IMP
8 BIT Tp-2 FLASH A/D CONVERTER
Tp-1
Tp PEAK HOLD
FORWARD ANGLE ① INT/SIZE TRANSLATION
VERSATILE INTERFACE ADAPTOR
VIA AQS.
FIFO MEMORY
A/D CONV.
PEAK HOLD
BACK ANGLE ② INT/SIZE TRANSLATION
INTERRUPT GENERATION
10MHz CLOCK
VARIABLE CONFIDENCE DIGITAL PEAK DETECT.
PARTICLE IN BEAM
MEMORY MANAGMENT LOGIC
VIA COMMUN-ICATION ①
15
MEMORY DECODING PROG. ARRAY LOGIC
DATA STORE MICROPROCESSOR 2MHz OMOS 6809
PAGE 3
PAGE 2
PAGE 1
PAGE 0 32K×8 DATA STORE
DATA AQUISITION STORED PROGRAM 2K EPROM
DATA AQUISITION SCRATCH PAD RAM 2K
BATTERY DATA RETENTION
DETACHABLE RAM CARTRIDGE

Fig.3 cont.


13
SWITCHING
BATTERY MONITOR CCTS
BATTERY
VIA CONTROL
HARDWARE CONTROL
EXTERNAL DATA PORT PRINTER/HOST
CALENDAR CLOCK. SEC. MIN. HOURS DAY MONTH YR.
CONTROL MICROPROCESSOR 2MHz CMOS 6809
DATA AQUIS. COMMAND AND MONITOR PORT
MEMORY DECODING
ENVIRONMENT CONTROL STORED PROGRAM
ENV. CONT. SCRATCH RAM
VIA COMS
2
1 2 3 BRK
4 5 6 DEL
7 8 9 ENTER
✱ 0 II
BACK LIT OPTIONS
8×30 CHAR LCD
✱WARNING✱
1
2
3
4
5
DATA TRANSFER

INTERNATIONAL SEARCH REPORT

International Application No PCT/GB 88/00972

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) [6]

According to International Patent Classification (IPC) or to both National Classification and IPC

IPC[4]: G 01 N 15/00

II. FIELDS SEARCHED

Minimum Documentation Searched [7]

Classification System	Classification Symbols
IPC[4]	G 01 N 15/00; G 01 N 15/02; G 01 N 15/14; G 01 N 21/53

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched [8]

III. DOCUMENTS CONSIDERED TO BE RELEVANT [9]

Category [*]	Citation of Document, [11] with indication, where appropriate, of the relevant passages [12]	Relevant to Claim No. [13]
Y	Patent Abstracts of Japan, vol. 11, no. 134 (P-571)(2581), 28th August 1987 & JP, A, 61274241 (HITACHI ELECTRONICS ENG.) 4th December 1986, see the whole abstract --	1,12
Y	GB, A, 2132767 (M. SALEHI) 11 July 1984, see page 2, lines 3-48; page 6, lines 31-127; figure 6 (cited in the application) --	1,12
A	Control Engineering, vol. 32, no. 1, January 1985, (Barrington, Illinois, US) G.J. Blickley: "Digital process measurements transmitted by fiber optic cables", pages 95,96, see page 95; page 96 up to "built into the transmitter" --	1,2
A	Aerosol Measurement, editor D. Lundgren et al. (Gainesville, FA, US) 1979 R.J. Sentell: "Computer graphics and analysis of atmospheric aerosol size distributions", pages 260-267,	3-8

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* Special categories of cited documents: [10]

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"&" document member of the same patent family

IV. CERTIFICATION

Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report
9th February 1989	- 9. 03. 89
International Searching Authority	**Signature of Authorized Officer**
EUROPEAN PATENT OFFICE	P.C.G. VAN DER PUTTEN

Form PCT/ISA/210 (second sheet) (January 1985)

III. DOCUMENTS CONSIDERED TO BE RELEVANT (CONTINUED FROM THE SECOND SHEET)

Category *	Citation of Document, with indication, where appropriate, of the relevant passages	Relevant to Claim No
	see pages 261-264 --	
A	IEEE Transactions on Nuclear Science, vol. NS-28, no. 1, February 1981 (New York, US) E. Anderson et al.: "Computer controlled meterological monitoring system", pages 255-257, see "general description", pages 256,257	1

ANNEX TO THE INTERNATIONAL SEARCH REPORT ON INTERNATIONAL PATENT APPLICATION NO. GB 8800972 SA 25161

This annex lists the patent family members relating to the patent documents cited in the above-mentioned international search report.
The members are as contained in the European Patent Office EDP file on 01/03/89
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Patent document cited in search report	Publication date	Patent family member(s)	Publication date
GB-A- 2132767	11-07-84	AU-A- 1984783	05-04-84

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For more details about this annex : see Official Journal of the European Patent Office, No. 12/82